A sustainable management of the hydric deficit in Large Sousse (Tunisia): local solutions to reduce the interregional transport of water

Nadia Sahtout, Mohamed Taoufik Bouzidi, Noureddine Mzoughi

Abstract— **The city of Sousse and its suburbs is confronted with a strong human and socio-economic attraction, but paradoxically, this area is very underprivileged on the hydric level. The transport of water from the surplus areas' water towards the overdrawn areas of Tunisia will not be able henceforth to constitute a durable solution because of a saturated network of adduction and distribution. A new vision of urban water management seeks to guide users towards a more rational behavior and to encourage the production of unconventional water. We present in this article a test of quantification of the water produced and scenarios of demand evolution from a prospective analysis.**

***Index Terms*— Hydraulic logistic, Large Sousse, urban water, integrated management, users actors, alternative production, prospective analysis.**

I. INTRODUCTION

The city of Sousse and its suburbs presents perfectly the whole of the problems of many Tunisian and Mediterranean cities, subjected to the aridity of the climate and enjoying a strong socio-economic attractions, but paradoxically, it is very underprivileged on the hydric level [1]. Water, a determining factor in dynamic sustainability of the urban area and its economic growth, represents a limiting factor of this development. The area has been confronted, and for a very long time, with this imbalance, and has succeeded in maintaining its hydraulic balance thanks to a strategy of transporting the surplus areas' water towards the overdrawn areas of Tunisia. Then it was all the know-how as regards hydraulic logistics which is requested to ensure the collection, the storage, the treatment, and the distribution of this water to the taps. Up to now, this strategy only focused on the increase in stocks and the transport of water. However, today's almost total mobilization of the underground and surface resources lays the foundation of a necessary change of the traditional management, which should aim, with a perspective to sustainable development of the resources, towards a reduction of the transport of water.

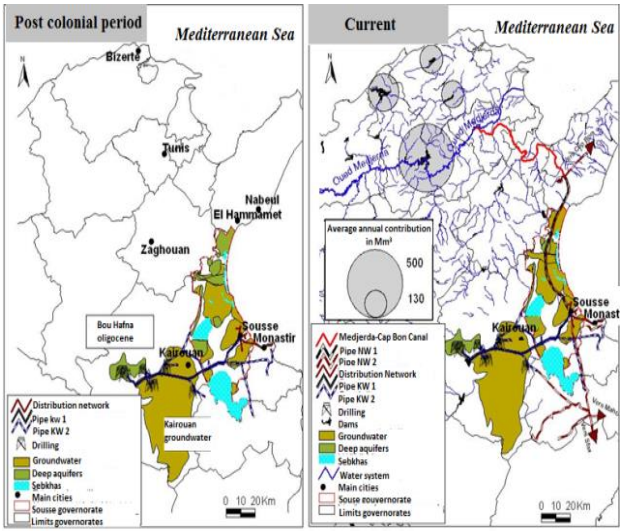
II. THE TRANSPORT OF WATER : A MANAGEMENT OF THE HYDRIC DEFICIT

A. *Interregional transfers to supply the Large Sousse network*

At the end of colonial occupation and the beginning of the independence, Souse has experienced a remarkable population growth and a diversified socio-economic development, directed towards new activities, such as, industry, tourism and urban development [2]. Hence, arised from a need to increase water stock very quickly, coming already at that time from the ground-waters of Kairouan, in order to answer the new demands. The supply network was rehabilitated with the installation of a teleprocessing system for a real- time control of the stock management. The deep ground water of Kairouan was sufficient to supply almost all the network of the Sahel till the beginning of the 80s. However, given the increase of needs and economic development in Large Sousse, the resources of Kairouan started to present signs of saturation. The Sahel area appeals to the surface water of the north for its supply since 1982. These waters come from what is called the system of the northern water [3], which makes the collection of Medjerda's waters and the under-basins of extreme north, thanks to large interconnected dams, which makes the hydraulic network extremely flexible and adaptable to risks. It is the know-how in regards to hydraulic logistics which could be deployed to solve regional disparities in water resources (map 1).

The weakness due to a total dependence for its supply, Sousse realizes one of the greatest performances, succeeding in serve more than 99% of its urban population [4]. However, we will observe through the water supply in urban spaces, it was detected that the limits of this strategy of transport started to be affected.

Map 1. The interregional transport of water towards the sahel

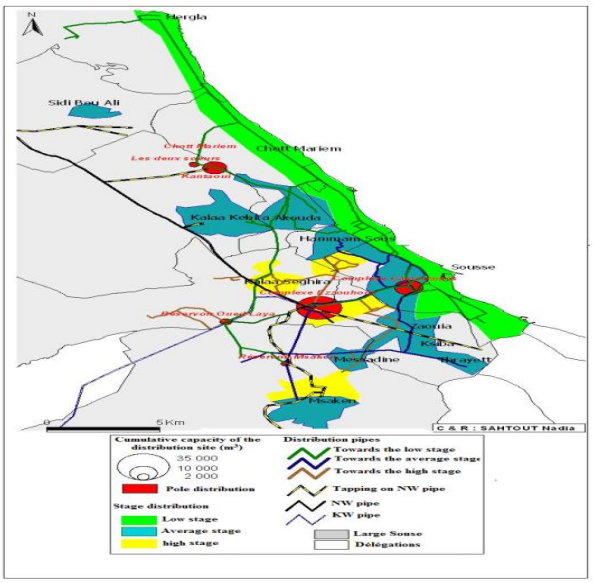


B. A saturated water supply in the urban spaces

The Ezzouhour complex, on the West of Souse, constitutes an interconnection pole of the various regional flows (water of Kairouan) and extra-regional flows (water of north) intended for the Sahel. It is in this site that operates the distribut ion of this mixed water. The general principle of the water supply is the gravitational pressure. Thus, in order to be able to supply the reservoirs of Sousse localities, the source must come systematically from a higher altitude. The water supply takes account of the stages of distribution (map 2). Indeed, the topography of Sousse requires the installation of a technical strategy in order to surmount the difference of altitude which constitutes the main obstacle for the water distribution. Thus, the SONEDE subdivided the territory in stages of distribution. The high stage is when the altitude exceeds 50 m, the average stage for the zone altitude ranging between 25 and 50 m, and the low stage for lower than 25 m. The low stage corresponds to the littoral zone. The average stage corresponds more or less to the physical limits traced by the national road n°1 (GP1) and the belt road of Sousse city. The low and average stages are fed from the half-pushed reservoir in the Ezzouhour complex of, with a regulation which is made in a gravitating way. The high stage distribution ensured from the tower reservoir which cannot function without electric motor-driven pumps.

Because of the five new zones to supply, the increasing needs to drinking water would require the reinforcement of the distribution network. This new zone represents a total surface area of more than 336 ha, including more than 81,000 inhabitants and approximately 13,200 residences: Sahloul IV (109 ha), Olympic city (100 ha), Hammam Maarouf (68 ha), The Casernes (5.5 ha), and The Technopole (54 ha).

Map 2. Distribution network of drinking water in the Large Sousse



The need will then increase in a linear way until 2030, regarded as being the date on which the occupation rate would reach its maximum. Also, the transport of water will not be able henceforth to constitute a durable solution in the future, because of potential conventional water which is now almost entirely mobilized and already will reach its maximum at the end of the decade.

III. Materials And Methods

A. Reached limits in the strategy of water transport

The limits are physical with immutable national resources which must satisfy the ever increasing needs. These limits are also economic and technical: as the remaining mobilized resources are increasingly distant and difficult to access, which decreases their profitability.

More especially as Tunisia do not escape the problems from the losses in the network from production and distribution. The extension of these water transmission networks increases failure risks. The losses mainly include breaks and leaks on the supply and distribution pipes, as well as the overflows of the accumulation reservoirs. The reduction of these losses is a major concern because the financial consequences are very heavy, and the degradations of the underground drains caused by the leaks are not without gravity in as dense urban fabric construction as Large Sousse There is an estimated 10,7% the rate loss of the distribution network towards Sousse, and despite of the important performances as regards to the optimal management of these networks of routing. This optimization implies the rehabilitation of the network, the improvement of connections materials, and the search of leaks through a telemetry system which allows a management in real time of the network supply from Kairouan and The North water. It is thus imperative, not only to take account of the saturation of these conventional resources, but still to give more importance with others solutions which can inflect the water consumption, and at the same time reduce the volumes of water transported between the areas.

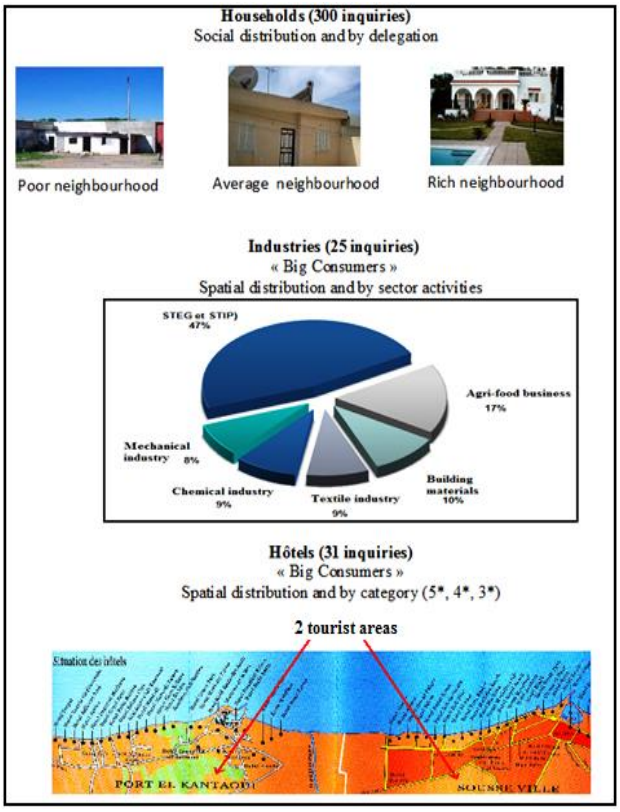
B. Users actors in a sustainable water management

According to a trend scenario of evolution, the demand for drinking water for Large Sousse should reach by a volume of almost 60 mm^3 in 2030. However, the conventional resources will reach a maximum mobilization before the end of the decade. The water of north, the main source of Large Sousse, already provide to full output approximately 50 mm^3 for all the Sahel. We have to anticipate the hydraulic imbalance threat, and to develop a new strategy, that will involve primarily to reconsider the vision of water. A new management must start.

It is the integrated management which is presented in the form of an alternative strategy in the resource management. This strategy must prevent to make water, a limiting factor of integration on the worldwide economy, or an interregional dependency, and finally a factor of imbalanced ecosystems. This new vision of integrated management seeks to guide the users towards a more rational use of water which maintains the request on a level lower than the resource. Management by the offer is not given up, but it simply covers another nature, with the production of an unconventional water, through the reuse of treated wastewaters and desalination.

This part presents a test of quantification of the water produced by the various users from a survey realized in 2007 near 300 households, 25 industries and 35 hotels in Large Sousse (fig1). These three types of users consume alone more than 90% of drinking water of the area. The investigation made it possible to note that all users try to save water. It is an extent of the recourse to the alternative resources by users who seek to use their own additional sources. The water of the public network indeed a burden increasingly heavy, from which seeks to abstract, partly at least. For a lot of enterprises this drinking water is not always essential.

Fig.1 the sample criteria



IV. RESULT AND DISCUSSION

Here only the sustainable alternatives developed by users are presented. Other not sustainable alternatives such as water from wells were not taken into account.

Rainwater cisterns: a modern return of impluviums

Today, it was noticed in ***the households*** a return of this practice even if the processes changed [5]. Before, they resort to the pluvial streaming. Now, they collect water from the roofs. The roofs became priority spaces because of the cities promiscuity, and the price of the land. In spite of a low regional rainfall, and an isohyets ranging between 400 and 300 mm of rains a year, the average production of these cisterns, for all Large Sousse, are estimated at more than **1.7 million m^3** of water. This quantity could be increased with a resizing effort of the receiving basins, which would taking account of the variability of precipitations. Those can exceed until 2 to 3 times the average precipitations, during the abundant years. An optimal resizing would make it possible to collect until twice and half the current quantities. This water constitutes already, for most delegations of the area, an important source of supply. Indeed, the water of impluviums represents more than 20% of the total inhabitants supply. It also fights against the floods, by blocking the urban streaming, thanks to the interception of the additional quantities when there is risings. The encouragement to the recourse of this alternative resource would be in conformity with the integrated management strategy.

The desalination of the sea water: additional quantities water to the long term

Desalination of sea water may be a viable alternative [6]. Very early, ***tourism*** sought to protect itself from the climatic risks of the area and the supply insecurity it generates. Most hotels developed their own resources. Some hotels show of a real capacity of anticipation in front of the challenges of water supply. They are, moreover, conscious of the impact of their own consumption on the costs and of the risk of a less competitiveness price, in a climate of international competition. Thus, it is engaged in projects of desalination by the process of osmosis opposite. One of the first experiments dates of 1996, with the taking of a brackishwater with 8 grams of salt by liters on the coasts of Sousse Hammam, and the acquisition of a station which pumps until 800 m^3 of raw water per day. These first experiments were a success and the leaders of the hotels launched out the experiment of the sea water desalination, more expensive than the water of the groundwater, because of its important rate salt.

The reverse osmosis water may be used to flushing toilets, watering and the cleaning of the filters of the swimming pool. These three posts of use represent the quarter of the total consumption. The production of desalinated water reached **255 000 m^3** in 2007. However, it is advisable to solve the problem of storage ant the recycling of the salt residues which, poured in the sea, become ecologically destructible.

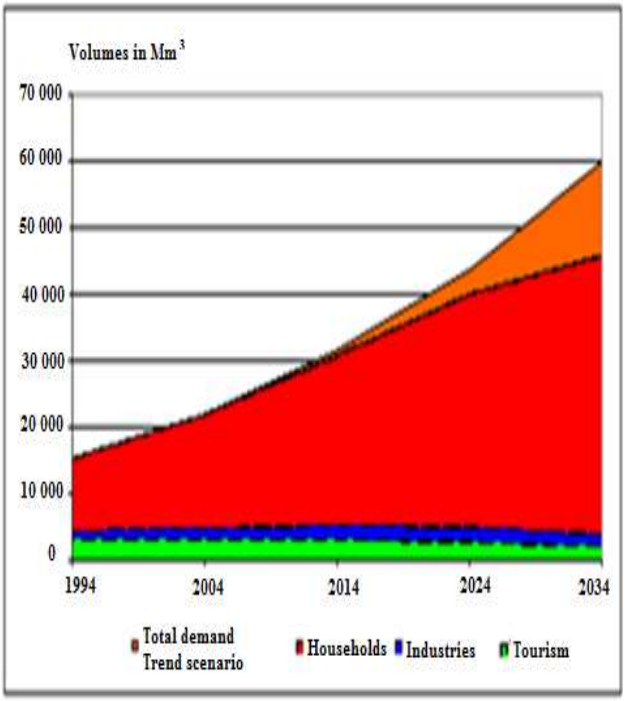
The recycling of wastewater: under-exploited industrial potential

In the industrial sector, the measures recommended by the Agenda 21, and which could moreover provide an important source of additional water, relate to the recycling of industrial water. Indeed, the industries have a great quantity available. This wastewater can represent until 20% of the consumed water. The investigation revealed that the recourse to this ecological practice is very weak. However, the national regulations force industry to install purification plants. Most of industries equipped in purifications stations reject, after treatment, their wastewater in the network, without seeking to re-use it. The main reason is the very expensive treatment of wastewaters. The recycled water represents only ***22 000 m³***, far behind the 300 000 m^3 water of wells produced by industries in Large Sousse.

Evolution of the demand through a systemic and prospective analysis

Our objective is to know through a systemic and prospective analysis, the possible evolutions of the relationship between populations, water resources, components of the environment and the sectors activities which are the pillars of regional development. The prospective scenarios show that we have to act today to confront the declining conventional resources during the next decades. A deceleration of this increase in the consumption does not seem inescapable. This is why developing an awareness of a better demand management is important. That implies an intensification of the campaign to raise public awareness and the development of a financial incentives (penalizing and, or encouraging) to inflect this request. According to this strategic scenario, the domestic and economic activities request should be reduced of almost 14 Mm³ before 2034. A choice of evolution rhythm was determinated for every variable (graph 1). The outcomes of the prospective analysis show that integrated management would make it possible to realize a real inflection of the request for nearly 9% in the medium term (2024), and already 30% in the long term (2034).

Graph 1. Evolution of the demand for total water between 1994 and 2034



CONCLUSION

The routing of water through a saturated network of adduction and distribution is a management of water question which can be inflected by the improving efficiency of the use of the resources, while trying to reduce the wasting, and to encourage users to be actors of the water management, by developing their own and durable alternatives. These additional resources would thus be produced at the local level, and would thus require less resort to the transport of the water from the surplus areas towards the overdrawn areas of Tunisia. This additional water would go not only in the direction of a more durable development of the resources, but also would reduce the regional dependences maintained by the recourse the transport water.

REFERENCES

[1]N. Sahtout, A. El Amri, M. Fourati, R. Majdoub, Les facteurs de la pauvreté hydrique du Grand Sousse : un déséquilibre en eau agricole en perspective ?, (2015) European Journal of Scientific Research, Vol. 136, n°3.

[2]R. Lamine, Tourisme et urbanité à Sousse, (1998) in Espaces et territoires. Tourisme et ville. Politique de la ville, tourisme et extension urbaine, Actes du Colloque de Hammamet 25-27 octobre 1997, sous la responsabilité de Abdallah Gabsi et Jean-Marie Miossec, Bulletin de la Société Languedocienne de Géographie Fascicule 3-4, tome 32, Juillet.

[3]A. Chérif, De l'eau libre à l'eau mobilisée. Mutations récentes et problèmes des aménagements hydrauliques en Tunisie du Nord, (2000) in L'eau, de la cellule au paysage, sous la dir. de Stanislas Wicherek, Elsevier, Collection Environnement, Paris, pp.265-277.

[4]SONEDE, Différents rapports des statistiques, Année 1990 à 2007, Direction Centrale de la Planification et des Etudes Générales, Division Statistique, Sousse.

[5]B. De Gouvello, « La récupération de l'eau de pluie dans les bâtiments : les enjeux d'une pratique de décentralisation partielle de la gestion des services d'eau », Cybergeo : European Journal of

Geography [En ligne], Dossiers, Séminaire de recherche du GDR Rés-Eau-Ville (CNRS 2524) "L'eau à la rencontre des territoires", Montpellier, France, 27-28 et 29 mai 2004, mis en ligne le 15 octobre 2004, consulté le 05 janvier 2016. URL : http://cybergeo.revues.org/1413 ; DOI : 10.4000/cybergeo.1413

[6]Boyé H., (2009) Dessalement de l'eau de mer : une ressource alternative", Technique, n°1/ 09 octobre.

Nadia Sahtout, Higher Institute of Transport and Logistics, Souse, Tunisia
Mohamed Taoufik Bouzidi, Higher Institute of Transport and Logistics, Souse, Tunisia
Noureddine Mzoughi, Higher Institute of Transport and Logistics, Souse, Tunisia